Journal of Physics: Conference Series **742** (2016) 012029 doi:10.1088/1742-6596/742/1/012029

Pion induced reaction with carbon and polyethylene targets obtained by HADES-GSI in 2014

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Abstract. In the summer of 2014, HADES was conducting measurements with secondary pion-beam using different targets. The program was devoted to measure dilepton radiation from baryonic resonances. In particular we investigated a sub-threshold coupling of ρ to baryonic resonances in the second resonance region (N(1520), N(1535)). Most of the beam time was dedicated to measurement of e^+e^- production from Polyethylene target at pion beam momentum of 0.69 GeV/c. In addition we run part of the time with pure carbon target. This allow us to study exclusive $\pi^- + p \to ne^-e^+$ channel. The normalization of spectra has been done using elastic scattering of pion on proton and carbon. The simulations of dilepton yields for π^0, Δ and N(1520) Dalitz decay using PLUTO was carried out.

1. Introduction

The HADES spectrometer [1] as shown in Fig. 1 is installed at SIS18 synchrotron in GSI Darmstadt, Germany. It is designed to measure systematically the production of electron-positron pairs in elementary and heavy-ion collisions at SIS18 energy range. It consists of 6 identical sectors covering the full azimuthal range and polar angles from $18° - 85°$ with respect to the beam direction. Each sector contains: A Ring Imaging CHerenkov (RICH) detector used for electron identification; two Mini-Drift Chambers (MDC) placed in front and two (MDC) placed behind the toroidal magnetic field used to determine momenta of charged particles; Time-Of-Flight detectors (TOF+RPC) and Pre-Shower detector improving the electron identification. The first level trigger is obtained by a fast multiplicity signal coming from the TOF wall, combined with a reaction signal from the START detector.

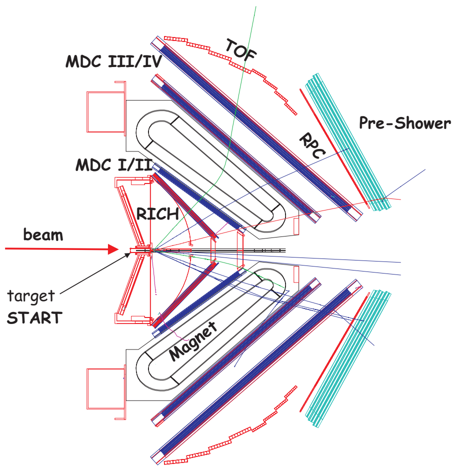

Figure 1. Schematic layout of the HADES detector.

2. Motivation

The addition of a secondary pion beam to the already available proton and heavy ion (HI) beams will allow to study properties of hadrons using the e^+e^- probe with the same detector system at different nuclear matter densities produced by pion, proton and HI beams. At ultra relativistic beam energies, the radiation in the spectral below the vector meson pole masses can be explained as $\pi^+\pi^-$ annihilation in the s-channel, at low beam energies the radiation of the fireball is better understood as electromagnetic decays of baryonic resonances. [2] The goal of the run was to investigate couplings of vector meson to baryon resonance, which play an important role in the description of in-medium ρ properties.

3. Experimental Layout

The π^- beam is generated by a primary ^{14}N beam, provided by the SIS18 synchrotron, with an intensity close to the space-charge limit of 0.8 -1.0 10^{11} ions/spill. The pions are transported to the HADES target, located 33m downstream of the production point by a beam-line composed of a lattice of 7 quadrupole and 2 dipole magnets, see Fig. 2. We used polyethylene (C_2H_4) as well as Carbon targets at pion beam momentum of 656 MeV/c, 690 MeV/c, 748 MeV/c, 800 MeV/c, see Table 1. The outgoing spectrum of pions is widely open both. Properties of the targets are given in Table 2.

Collected statistics in beam time AUG14/SEP14			
Target	**p**(MeV/c)	**Sum of events** (10^6)	**Data** (h)
PE	690	774.7	175.56
PE	748	76.5	11.61
PE	656	42.4	14,08
PE	800	52.4	7,48
C	690	115,7	13,06
C	800	41,2	6,27
C	748	42,2	6,8
C	656	41,9	14,75

Table 1. Collected statistics in beam time Aug14/Sep14

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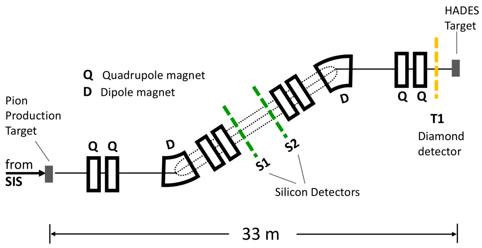

Figure 2. Schematic drawing of the pion beam-line

Target	PE=C_2H_4	C
Diameter (cm)	1.2	1.2
Length cm	4.6	2.52
M (g/mol)	28	12
Density(g/cm^3)	0.93	1.85
No. of carbon atoms	$18.4 \cdot 10^{22}$	$23.4 \cdot 10^{22}$

Table 2. Properties of the targets

3.1. Subtraction of Carbon contribution from PE target

First of all, we have to normalize the signal from both targets with the number of pions that went through the START detector. $Signal - scaled = \frac{Inv.Mass-CB}{Livetime}$ where $Livetime = \frac{M2\&\&START}{M2\&\&START-rate}$, where $M2\&\&START$ is the number of triggers, and $M2\&\&START - rate$ with the correction of dead time. The yield will be finally normalized by Signal-scaled/START. Finally using the corresponding factor $f = \frac{No.\ C\ atoms\ in\ PE}{No.\ C\ atoms\ in\ C} = 0.78$ taken from Table 2, we can subtract the C contribution from the PE using the formula: $H = PE - f \cdot C$. To check the consistency of the procedure, we normalized by the same way the number of $\pi^- + p$ and $\pi^- + C$ elastic scattering events collected during the experiment, see Fig. 3.

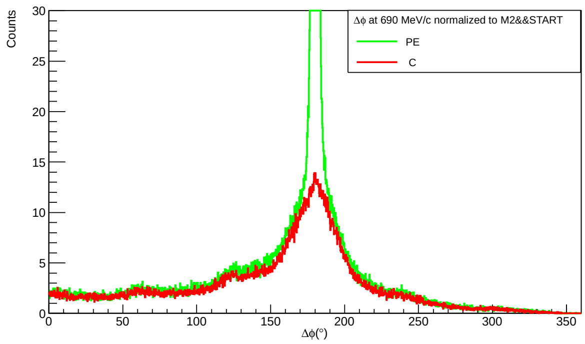

Figure 3. $\Delta\phi$ Spectra of elastically scattered pions scaled by the normalization factor

4. Simulations

In the analysis of simulations events were generated following theoretical distributions, using a comprehensive and modular ROOT-based event generator called PLUTO [2] developed by the HADES collaboration. For the simulations of $\pi^- + C$ we used a quasi-free model normalized by a factor 2, the list of channels simulated is shown in Table 3. No form factors are used for the treatment of the Dalitz decay of N(1520) and $\Delta(1232)$.

Channel	$\sigma\,(mb)$	Branching Ratio(%)	Data source
$\pi^- + p \to n\pi^0$	9.2	0.012	1
$\pi^- + p \to n\pi^0\pi^0 \quad \pi^- + p \to p\pi^0\pi^0\ (\pi^0 \to \gamma e^+e^-)$	7.4	$4 \cdot 10^{-5}$	2
$\pi^- + p \to \Delta(\Delta \to Ne^+e^-)$	8.4	$4 \cdot 10^{-5}$	3
$\pi^- + p \to N\,(1520)^0\,(N\,(1520) \to ne^+e^-)$	20.5	$4 \cdot 10^{-5}$	4
$\pi^- + p \to n\eta(\eta \to \gamma e^+e^-)$	$0.3(p)\,0.7\,(C)$	0.006	5
$\pi^- p \to n\rho(\rho \to e^+e^-)$	4	$4 \cdot 10^{-5}$	6

Table 3. Cocktail source. 1: Landolt-Börnstein (L-B) for p $\in (0.6 - 0.72)\,MeV/c$ [4], 2: Crystall Ball for $\sqrt{s} = 1.461\ GeV/c^2$ with 20% reduction [5], 3: From single and double pion production cross sections, 4: From single and double pion production cross sections, 5: Parametrization from L-B data, 6: Manley' s analysis [6].

4.1. Inclusive e^+e^- cocktail

The inclusive electron pair differential cross section as a function of invariant mass and missing mass preliminary of the dielectron with respect to the pion-nucleon system were compared with the expected contributions for $\pi^- + C$ and $\pi^- + p$ simulations obtained from experiment by PLUTO event generator. The result of simulation are shown in Fig. 3.

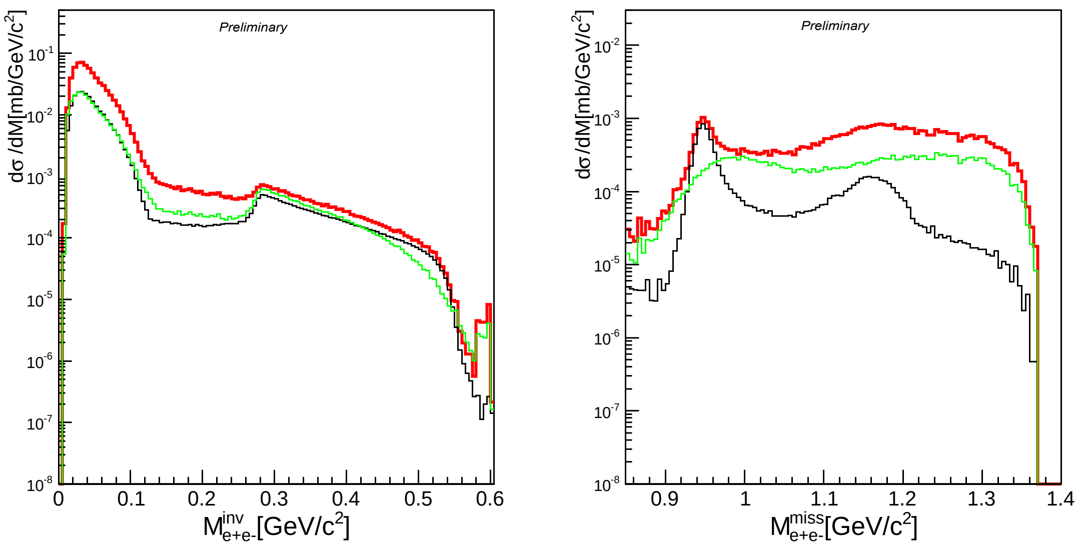

Figure 4. Left: e^+e^- Invariant mass distribution. **Right**: e^+e^- Missing mass distribution. Black line: Sum of $\pi^- + p$ simulations, Green line: Sum of $\pi^- + C$ simulations, Red line: Sum of $\pi^- + PE$ simulations

4.2. Exclusive e^+e^- cocktail

The exclusive electron pair differential cross sections as a function of invariant mass and missing mass with the proper cuts to select the $\pi^- + p \to ne^+e^-$ channel decays for $\pi^- + p$ simulations obtained by PLUTO event generator are shown below. It can be seen that the η contribution is very efficiently suppressed. The N(1520) Dalitz decay contribution falls off very rapidly at large invariant masses, due to the absence of form factor. The ρ contribution is dominating for invariant masses larger than 0.25 GeV/c^2 and consists of both resonant (i.e. via N(1520) decay) and non-resonant processes).

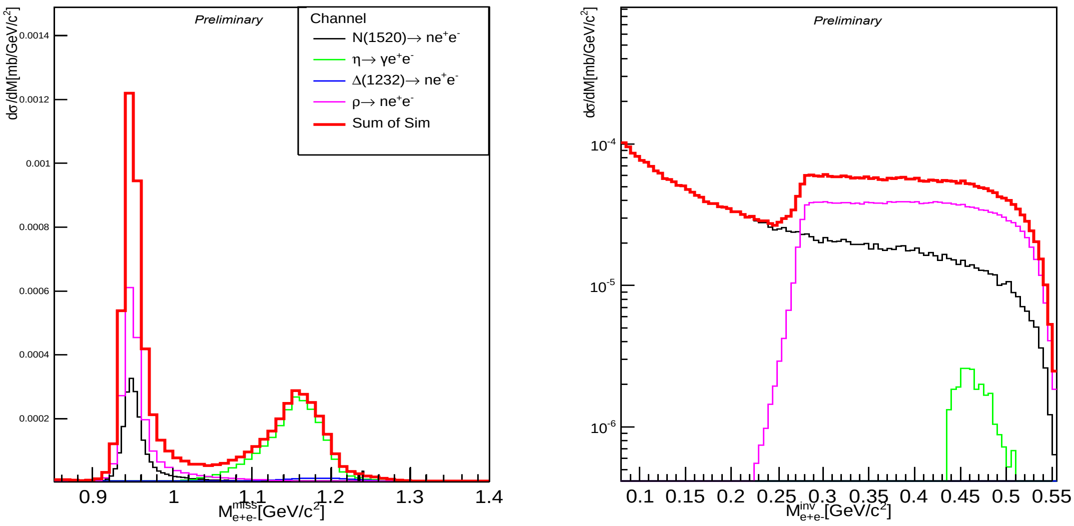

Figure 5. Left: Missing mass for $M^{inv}_{e^+e^-} > 0.12\ GeV/c^2$. **Right**: Invariant Mass for $0.9 < M^{miss}_{e^+e^-} < 1.0\ GeV/c^2$

5. Conclusion

The differential distributions obtained in the experiment will be compared to the e^+e^- cocktail from η, ρ, $\Delta(1232)$ and N(1520). It is expected that e^+e^- yield of invariant mass above 0.25 GeV/c^2 region corresponding to the missing mass between $[0.9 - 1.0]$ GeV/c^2 will be consisted with $N(1520) \to n\rho \to ne^+e^-$. Models associate the excess of dilepton measured in HI reactions with the excitation and decay of baryonic resonances into dileptons via intermediate ρ meson.

6. Acknowledgements

The collaboration gratefully acknowledges to: INFN-LNS Catania(Italy); LIP Coimbra(Portugal):PTDC/FIS/113339/2009; SIP JUC Cracow(Poland):NN202198639; GSI Darmstadt(Germany): Helmholtz Alliance HA216/EMMI; TU Darmstadt (Germany): VH-NG-823, Helmholtz Alliance HA216/EMMI; HZDR, Dresden(Germany):283286, 05P12CRGHE; Goethe University, Frankfurt (Germany):Helmholtz Alliance HA216/EMMI, HIC for FAIR (LOEWE), GSI FE, BMBF 06FY9100I, HGS-Hire, H-QM research school TU Munchen, Garching (Germany): BMBF 06MT7180; JLU Giessen (Germany):BMBF:05P12RGGHM; University Cyprus, Nicosia (Cyprus):UCY/3411-23100; IPN Orsay, Orsay Cedex (France): CNRS/IN2P3; NPI AS CR, Rez, (Czech Republic): GACR 13-067595 and LM201549 of MSMT of CR.

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